

Problem 8C

NEWTON'S SECOND LAW FOR ROTATION

PROBLEM

The giant sequoia General Sherman in California has a mass of about 2.00×10^6 kg, making it the most massive tree in the world. Its height of 83.0 m is also impressive. Imagine a uniform bar with the same mass and length as the tree. If this bar is rotated about an axis that is perpendicular to and passes through the bar's midpoint, how large an angular acceleration would result from a torque of 4.60×10^7 N•m? (Note: Assume the bar is thin.)

SOLUTION

Given: $M = 2.00 \times 10^6$ kg
 $\ell = 83.0$ m
 $\tau = 4.60 \times 10^7$ N•m

Unknown: $\alpha \times ?$

Calculate the bar's moment of inertia using the formula for a thin rod with the axis of rotation at its center.

$$I = \frac{1}{12} M \ell^2 = \frac{1}{12} (2.00 \times 10^6 \text{ kg})(83.0 \text{ m})^2 = 1.15 \times 10^9 \text{ kg}\cdot\text{m}^2$$

Now use the equation for Newton's second law for rotating objects. Rearrange the equation to solve for angular acceleration.

$$\tau = I\alpha$$

$$\alpha = \frac{\tau}{I} = \frac{(4.60 \times 10^7 \text{ N}\cdot\text{m})}{(1.15 \times 10^9 \text{ kg}\cdot\text{m}^2)} = \boxed{4.00 \times 10^{-2} \text{ rad/s}^2}$$

ADDITIONAL PRACTICE

- One of the largest Ferris wheels currently in existence is in Yokohama, Japan. The wheel has a radius of 50.0 m and a mass of 1.20×10^6 kg. If a torque of 1.0×10^9 N•m is needed to turn the wheel from a state of rest, what would the wheel's angular acceleration be? Treat the wheel as a thin hoop.
- In 1992, Jacky Vranken from Belgium attained a speed of more than 250 km/h on just the back wheel of a motorcycle. Assume that all of the back wheel's mass is located at its outer edge. If the wheel has a mass of 22 kg and a radius of 0.36 m, what is the wheel's angular acceleration when a torque of 5.7 N•m acts on the wheel?
- In 1995, a fully functional pencil with a mass of 24 kg and a length of 2.74 m was made. Suppose this pencil is suspended at its midpoint and a force of 1.8 N is applied perpendicular to its end, causing it to rotate. What is the angular acceleration of the pencil?

4. The turbines at the Grand Coulee Third Power Plant in the state of Washington have rotors with a mass of 4.07×10^5 kg and a radius of 5.0 m each. What angular acceleration would one of these rotors have if a torque of 5.0×10^4 N•m were applied? Assume the rotor is a uniform disk.
5. J. C. Payne of Texas amassed a ball of string that had a radius of 2.00 m. Suppose a force of 208 N was applied tangentially to the ball's surface in order to give the ball an angular acceleration of 3.20×10^{-2} rad/s². What was the ball's moment of inertia?
6. The heaviest member of British Parliament ever was Sir Cyril Smith. Calculate his peak mass by finding first his moment of inertia from the following situation. If Sir Cyril were to have ridden on a merry-go-round with a radius of 8.0 m, a torque of 7.3×10^3 N•m would have been needed to provide him with an angular acceleration of 0.60 rad/s².
7. In 1975, a centrifuge at a research center in England made a carbon-fiber rod spin about its center so fast that the tangential speed of the rod's tips was about 2.0 km/s. The length of the rod was 15.0 cm. If it took 80.0 s for a torque of 0.20 N•m to bring the rod to rest from its maximum speed, what was the rod's moment of inertia?
8. The largest tricycle ever built had rear wheels that were almost 1.70 m in diameter. Neglecting the mass of the spokes, the moment of inertia of one of these wheels is equal to that of a thin hoop rotated about its symmetry axis. Find the wheel's moment of inertia and its mass if a torque of 125 N•m is applied to the wheel so that in 2.0 s the wheel's angular speed increases from 0 rad/s to 12 rad/s.
9. In 1990, a cherry pie with a radius of 3.00 m and a mass of 17×10^3 kg was baked in Canada. Suppose the pie was placed on a light rotating platform attached to a motor. If this motor brought the angular speed of the pie from 0 rad/s to 3.46 rad/s in 12 s, what was the torque the motor must have produced? Assume the mass of the platform was negligible and the pie was a uniformly solid disk.
10. In just over a month in 1962, a shaft almost 4.00×10^8 m deep and with a radius of 4.0 m was drilled in South Africa. The mass of the soil taken out was about 1.0×10^8 kg. Imagine a rigid cylinder with a mass, radius, and length equal to these values. If this cylinder rotates about its symmetry axis so that it undergoes a constant angular acceleration from 0 rad/s to 0.080 rad/s in 60.0 s, how large a torque must act on the cylinder?
11. In 1993, a bowl in Canada was filled with strawberries. The mass of the bowl and strawberries combined was 2390 kg, and the moment of inertia about the symmetry axis was estimated to be 2.40×10^3 kg•m². Suppose a constant angular acceleration was applied to the bowl so that it made its first two complete rotations in 6.00 s. How large was the torque that acted on the bowl?

- 12.** A steel ax with a mass of 7.0×10^3 kg and a length of 18.3 m was made in Canada. If Paul Bunyan were to take a swing with such an ax, what torque would he have to produce in order for the blade to have a tangential acceleration of 25 m/s^2 ? Assume that the blade follows a circle with a radius equal to the ax handle's length and that nearly all of the mass is concentrated in the blade.